

## Chapter 3

### Greenhouse Gas Emissions

Summary Statistics from Tables in this Chapter

Source			
Table 3.1	Carbon emissions (million metric tonnes)	1990	1997
	<i>France</i>	103	102
	<i>Germany</i>	267	234
	<i>United Kingdom</i>	166	156
	<i>Japan</i>	274	297
	<i>United States</i>	1,345	1,480
	<i>China</i>	620	822
	<i>India</i>	153	236
Table 3.3	Transportation share of U.S. carbon dioxide emissions from fossil fuel consumption		
	<i>1985</i>		30.9%
	<i>1990</i>		32.0%
	<i>1999</i>		32.8%
Table 3.4	Carbon dioxide emissions from U.S. transportation energy use, 1999		
	<i>Motor gasoline</i>		60.3%
	<i>Liquified petroleum gas</i>		0.1%
	<i>Jet fuel</i>		13.4%
	<i>Distillate fuel</i>		20.2%
	<i>Residual fuel</i>		3.5%
	<i>Lubricants</i>		0.4%
	<i>Aviation gas</i>		0.1%
	<i>Natural gas</i>		1.9%
	<i>Electricity</i>		0.2%

**Table 3.1**  
**World Carbon Emissions, 1990 and 1997**

	1990		1997	
	Million metric tons	Percent of emissions from oil use	Million metric tons	Percent of emissions from oil use
Industrialized countries	2,850	49%	3,039	49%
United States	1,345	44%	1,480	42%
Canada	127	48%	142	46%
Mexico	81	75%	94	74%
United Kingdom	166	40%	156	41%
France	103	65%	102	69%
Germany	267	37%	234	45%
Italy	113	65%	116	66%
Netherlands	60	48%	64	45%
Other Western Europe	224	63%	246	65%
Japan	274	65%	297	63%
Other industrialized countries	90	44%	108	42%
Eastern Europe	1,337	30%	878	25%
Developing countries	1,649	41%	2,258	41%
China	620	16%	822	18%
India	153	29%	236	28%
Other developing countries	876	13%	1,200	3%
Total World	5,836	42%	6,175	43%

**Source:**

U.S. Department of Energy, Energy Information Administration, *International Energy Outlook 2000*, Washington, DC, March 2000, Tables A10 and A11.

*Global Warming Potentials (GWP) were developed to allow comparison of each greenhouse gas' ability to trap heat in the atmosphere relative to carbon dioxide. Extensive research has been performed and it has been discovered that the effects of various gases on global warming are too complex to be precisely summarized by a single number. Further understanding of the subject also causes frequent changes to estimates. Despite that, the scientific community has developed approximations, which are shown below. Most analysts use the 100-year time horizon.*

**Table 3.2**  
**Numerical Estimates of Global Warming Potentials Compared With Carbon Dioxide**  
**(kilogram of gas per kilogram of carbon dioxide)**

Gas	Lifetime (years)	Global warming potential direct effect for time horizons of		
		20 years	100 years	500 years
Carbon Dioxide	Variable	1	1	1
Methane	12 ± 3	56	21	7
Nitrous Oxide	120	280	310	170
HFCs, PFCs, and other gases				
HFC-23	264	9,200	12,100	9,900
HFC-125	33	4,800	3,200	11
HFC-134a	15	3,300	1,300	420
HFC-152a	2	460	140	42
HFC-227ea	37	4,300	2,900	950
Perfluoromethane	50,000	4,400	6,500	10,000
Perfluoroethane	10,000	6,200	9,200	14,000
Sulfur hexafluoride	3,200	16,300	23,900	34,900

**Source:**

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1999*, Washington, DC, October 2000, p. 8. Original source: Intergovernmental Panel on Climate Change. (Additional resources: [www.eia.doe.gov](http://www.eia.doe.gov), [www.ipcc.ch](http://www.ipcc.ch))

**Note:**

The typical uncertainty for global warming potentials is estimated by the Intergovernmental Panel on Climate Change at ± 35 percent.

*Carbon dioxide emissions in 1999 were 13% higher than in 1990. Carbon dioxide accounts for the majority of greenhouse gases.*

**Table 3.3**  
**Estimated U.S. Emissions of Greenhouse Gases, 1990–99**

Greenhouse gas	Unit of measure <sup>a</sup>	1990	1995	1998	1999
Carbon dioxide	million metric tons of gas	4,951.9	5,260.6	5,527.1	5,598.2
	million metric tons of carbon	1,351.0	1,435.0	1,507.0	1,527.0
Methane	million metric tons of gas	31.7	31.2	29.3	28.8
	million metric tons of carbon (gwp) <sup>b</sup>	182.0	179.0	168.0	165.0
Nitrous oxide	million metric tons of gas	1.2	1.3	1.2	1.2
	million metric tons of carbon (gwp) <sup>b</sup>	99.0	106.0	103.0	103.0
HFCs, PFCs, and SF <sub>6</sub> <sup>c</sup>	million metric tons of carbon (gwp) <sup>b</sup>	24.0	29.0	40.0	38.0

**Source:**

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1999*, Washington, DC, October 2000, pp. vii, viii. (Additional resources: [www.eia.doe.gov](http://www.eia.doe.gov))

<sup>a</sup>Gases that contain carbon can be measured either in terms of the full molecular weight of the gas or just in terms of their carbon content. See Appendix B, Table B.5 for details.

<sup>b</sup>Based on global warming potential.

<sup>c</sup>HFC-hydrofluorocarbons. PFC-perfluorocarbons. SF<sub>6</sub>=sulfur hexafluoride.

*Gases which contain carbon can be measured in terms of the full molecular weight of the gas or just in terms of their carbon content. This table presents carbon content. The ratio of the weight of carbon to carbon dioxide is 0.2727. The transportation sector accounts for approximately one-third of carbon dioxide emissions.*

**Table 3.4**  
**U.S. Carbon Dioxide Emissions from Fossil Energy Consumption**  
**by End-Use Sector, 1985–99<sup>a</sup>**  
**(million metric tons of carbon)**

End use sector	1985	1990	1995	1996	1997	1998	1999
Residential	245.8	254.2	273.4	289.6	288.6	288.8	290.1
Commercial	189.6	207.7	220.6	229.2	241.5	244.5	243.5
Industrial	424.1	454.8	469.2	483.8	489.7	480.2	481.2
Transportation	384.4	431.8	457.8	468.9	473.6	481.9	496.1
Percentage	30.9%	32.0%	32.2%	31.9%	31.7%	32.2%	32.8%
<b>Total energy</b>	<b>1,243.9</b>	<b>1,348.6</b>	<b>1,421.0</b>	<b>1,471.5</b>	<b>1,493.4</b>	<b>1,495.4</b>	<b>1,510.8</b>

**Source:**

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1999*, Washington, DC, October 2000, p. 25, and annual. (Additional resources: [www.eia.doe.gov](http://www.eia.doe.gov))

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<sup>a</sup>Includes energy from petroleum, coal, and natural gas. Electric utility emissions are distributed across consumption sectors.

*Most U.S. carbon dioxide emissions come from petroleum fuels (98%). Motor gasoline has been responsible for about 60% of U.S. carbon dioxide emissions over the last twenty years.*

**Table 3.5**  
**U.S. Carbon Dioxide Emissions from Energy Use in the Transportation Sector, 1980–99**  
**(million metric tons of carbon)**

Fuel	1980		1990		1999	
	Emissions	Percentage	Emissions	Percentage	Emissions	Percentage
<b>Petroleum</b>						
Motor gasoline	238.1	62.9%	260.6	60.4%	299.1	60.3%
LPG <sup>a</sup>	0.3	0.1%	0.4	0.1%	0.3	0.1%
Jet fuel	42.0	11.1%	60.1	13.9%	66.3	13.4%
Distillate fuel	55.3	14.6%	75.7	17.5%	100.1	20.2%
Residual fuel	30.0	7.9%	21.9	5.1%	17.5	3.5%
Lubricants	1.8	0.5%	1.8	0.4%	1.8	0.4%
Aviation gas	1.2	0.3%	0.8	0.2%	0.7	0.1%
<b>Total</b>	<b>368.7</b>	<b>97.4%</b>	<b>421.2</b>	<b>97.5%</b>	<b>485.8</b>	<b>97.9%</b>
<b>Other energy</b>						
Natural gas	9.4	2.5%	9.8	2.3%	9.5	1.9%
Electricity <sup>b</sup>	0.3	0.1%	0.7	0.2%	0.8	0.2%
<b>Total</b>	<b>378.4</b>	<b>100.0%</b>	<b>432.1</b>	<b>100.0%</b>	<b>496.1</b>	<b>100.0%</b>

**Source:**

U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States, 1999*, Washington, DC, October 2000, p. 27, and annual. (Additional resources: [www.eia.doe.gov](http://www.eia.doe.gov))

<sup>a</sup>Liquified petroleum gas.

<sup>b</sup>Share of total electric utility carbon dioxide emissions weighted by sales to the transportation sector.

## The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model

The energy in greenhouse gas estimates of the most recent version (Beta Version 1.6) of the GREET model are displayed in the next table. The model estimates the full fuel-cycle emissions and energy use associated with various transportation fuels and advanced transportation technologies for light-duty vehicles. It calculates fuel-cycle emissions of **three greenhouse gases** (carbon dioxide, methane, and nitrous oxide) and five criteria pollutants (volatile organic compounds, carbon monoxide, nitrogen oxides, sulfur oxides, and particulate matter measuring 10 microns or less). **See Chapter 4 for the criteria pollutant data from GREET.** The model also calculates the total fuel-cycle energy consumption, fossil fuel consumption, and petroleum consumption using various transportation fuels. The fuel cycles that are included in the GREET model are:

- petroleum to conventional gasoline, reformulated gasoline, conventional diesel, reformulated diesel, liquefied petroleum gas, and electricity via residual oil;
- natural gas to compressed natural gas, liquefied natural gas, liquefied petroleum gas, methanol, Fischer-Tropsch diesel, dimethyl ether, hydrogen, and electricity;
- coal to electricity;
- uranium to electricity;
- renewable energy (hydropower, solar energy, and wind) to electricity;
- corn, woody biomass, and herbaceous biomass to ethanol;
- soybeans to biodiesel; and
- landfill gases to methanol.

For additional information about the GREET model, see *GREET 1.5 – Transportation Fuel-Cycle Model, Volume 1: Methodology, Development, Use and Results*, ANL/ESD-39, Vol. 1, August 1999, or contact:

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GREET Web Site:  
<http://www.transportation.anl.gov/ttrdc/greet/>

### Acronyms and Terms Used on Table 3.6

BD20	mixture of 20% biodiesel and 80% conventional diesel (by volume)
CA	California
CH <sub>4</sub>	methane
CIDI	compression ignition, direct injection
CIDIV	compression ignition, direct injection vehicle
CNG	compressed natural gas
CNGV	compressed natural gas vehicle
CO <sub>2</sub>	carbon dioxide
DME	dimethyl ether
E90	mixture of 90% ethanol and 10% gasoline (by volume)
EtOH	ethanol
EtOHV	ethanol vehicle
EV	electric vehicle
FCV	fuel-cell vehicle
FRFG	Federal reformulated gasoline
FT	Fischer-Tropsch
FTD	Fischer-Tropsch diesel
G.H <sub>2</sub>	gaseous hydrogen
GC	grid-connected (charge depleting)
GGE	gasoline gallon equivalent
GHGs	greenhouse gases
GI	grid-independent (charge sustaining)
GV	gasoline vehicle
HEV	hybrid electric vehicle
L.H <sub>2</sub>	liquid hydrogen
LS	low-sulfur
M90	mixture of 90% methanol and 10% gasoline by volume
MeOH	methanol
MeOHV	methanol vehicle
N <sub>2</sub> O	nitrous oxide
NA	North American
NE	northeast
NG	natural gas
NNA	non-North American
SI	spark ignition
urban	Emissions occurring within air quality control regions in the U.S. These regions have emission controls in place in order to meet or maintain air quality standards.
US	United States



**Table 3.6**  
**Fuel-Cycle Energy and Greenhouse Gas Emission Changes**  
**of Alternative and Advanced Vehicle/Fuel Systems**  
**(percentage relative to internal combustion engine vehicles**  
**fueled with reformulated gasoline)**

	GV: FRFG (btu/mile or grams/mile)	CNGV: NA NG	CNGV: NNA NG	Propane vehicle	M90 MeOHV: NA NG	M90 MeOHV: NNA NG	E90 EtOHV: corn	E90 EtOHV: cellulosic biomass	GI SI HEV: FRFG	GC SI HEV: FRFG
MPG - GGE	24.1	24.1	24.1	25.3	25.3	25.3	25.3	25.3	33.8	54.1
Total energy	5,891	-9.5%	1.2%	-16.2%	14.6%	16.3%	10.4%	53.8%	-28.6%	-40.7%
Fossil fuels	5,872	-9.7%	1.0%	-16.0%	14.9%	16.6%	-45.3%	-79.5%	-28.6%	-43.1%
Petroleum	4,665	-99.5%	-99.5%	-59.1%	-79.1%	-79.9%	-75.0%	-74.9%	-28.6%	-57.7%
CO2	446	-26.8%	-18.5%	-20.1%	-5.7%	-4.3%	-41.0%	-88.9%	-28.6%	-40.1%
CH4	0.684	111.0%	216.8%	-21.9%	-9.5%	8.5%	-27.6%	-63.3%	-25.9%	-39.4%
N2O	0.030	-49.6%	-46.4%	-3.1%	0.5%	1.3%	448.3%	474.8%	-1.6%	-29.2%
GHGs	469	-23.1%	-13.1%	-19.8%	-5.7%	-3.9%	-31.0%	-77.1%	-28.0%	-39.9%

	CIDIV: LS diesel	CIDIV: FTD, NA NG	CIDIV: FTD, NNA NG	CIDIV: BD20	GI CIDI HEV: LS diesel	GC CIDI HEV: LS diesel	EV: US mix	EV: NE US mix	EV: CA mix
MPG - GGE	29.6	29.6	29.6	29.6	41.0	57.7	84.4	84.4	84.4
Total energy	-21.7%	8.7%	10.4%	-19.0%	-43.6%	-47.2%	-45.1%	-46.2%	-50.6%
Fossil fuels	-21.7%	9.0%	10.8%	-19.1%	-43.6%	-49.6%	-52.5%	-55.6%	-61.9%
Petroleum	-10.4%	-99.0%	-98.5%	-25.5%	-35.4%	-59.7%	-98.4%	-97.5%	-99.7%
CO2	-17.1%	-13.4%	-12.1%	-28.4%	-40.2%	-44.6%	-43.5%	-53.4%	-61.5%
CH4	-40.4%	-40.3%	-24.9%	-44.2%	-56.6%	-56.3%	-48.8%	-36.3%	-43.2%
N2O	-42.3%	-44.9%	-30.0%	-34.1%	-43.3%	-57.0%	-84.1%	-87.1%	-88.6%
GHGs	-18.3%	-14.8%	-12.7%	-29.0%	-40.8%	-45.2%	-44.5%	-53.5%	-61.5%

	FCV: G.H2, central plant, NA NG	FCV: G.H2, central plant, NNA NG	FCV: G.H2, refueling station, NA NG	FCV: G.H2, refueling station, NNA NG	FCV: G.H2, central electrolysis, renewables	FCV: G.H2, station electrolysis, US generation mix
MPG - GGE	50.7	50.7	50.7	50.7	50.7	50.7
Total energy	-35.6%	-30.0%	-32.9%	-28.4%	-37.6%	40.5%
Fossil fuels	-36.6%	-31.0%	-33.2%	-28.6%	-91.9%	22.4%
Petroleum	-99.2%	-99.3%	-99.7%	-99.6%	-99.5%	-96.3%
CO2	-47.7%	-42.7%	-46.9%	-43.3%	-90.6%	44.7%
CH4	-50.1%	-4.3%	-36.2%	-3.3%	-89.5%	62.6%
N2O	-94.9%	-93.2%	-94.8%	-93.3%	-97.7%	-64.9%
GHGs	-48.7%	-42.6%	-47.5%	-43.2%	-90.7%	43.3%

(Table continued on next page)

**Note:**

See page preceding Table 3.6 for acronym definitions.

**Table 3.6 (Continued)**  
**Fuel-Cycle Energy and Emission Changes of Alternative and Advanced Vehicle/Fuel Systems**  
**(percentage relative to intenal combustion engine vehicles fueled with reformulated gasoline)**

	FCV: L.H2, central plant, NA NG	FCV: L.H2, central plant, NNA NG	FCV: L.H2, refueling station, NA NG	FCV: L.H2, refueling station, NNA NG	FCV: L.H2, central electrolysis, renewables	FCV: L.H2, station electrolysis, US generation mix
MPG - GGE	50.7	50.7	50.7	50.7	50.7	50.7
Total energy	-11.6%	-8.5%	12.4%	19.5%	-44.0%	105.3%
Fossil fuels	-11.4%	-8.4%	6.0%	12.9%	-98.7%	61.7%
Petroleum	-99.3%	-99.0%	-98.4%	-98.4%	-99.4%	-95.2%
CO2	-28.8%	-25.4%	-1.3%	2.4%	-98.8%	91.1%
CH4	-25.1%	-21.6%	6.5%	81.3%	-98.8%	114.7%
N2O	-86.2%	-85.5%	-84.3%	-82.7%	-99.6%	-53.7%
GHGs	-29.7%	-26.4%	-2.5%	2.9%	-98.8%	89.2%

	FCV: MeOH, NA NG	FCV: MeOH, NNA NG	FCV: gasoline	FCV: cellulosic EtOH	FCV: CNG, NA NG	FCV: CNG, NNA NG	FCV: FT naphtha, NNA NG	FCV: crude naphtha
MPG - GGE	42.2	42.2	37.4	39.3	37.4	37.4	37.4	37.4
Total energy	-28.7%	-27.4%	-35.5%	19.9%	-41.6%	-34.7%	-10.3%	-38.6%
Fossil fuels	-28.5%	-27.2%	-35.5%	-96.9%	-41.7%	-34.8%	-10.0%	-38.6%
Petroleum	-98.5%	-98.1%	-35.5%	-94.4%	-99.7%	-99.7%	-98.7%	-36.4%
CO2	-43.5%	-42.5%	-35.5%	-105.1%	-52.7%	-47.4%	-32.7%	-41.3%
CH4	-46.7%	-33.5%	-39.3%	-91.8%	15.0%	85.2%	-38.8%	-41.8%
N2O	-77.4%	-76.7%	-77.4%	338.7%	-79.1%	-77.0%	-79.9%	-78.6%
GHGs	-44.3%	-42.9%	-36.3%	-96.0%	-51.1%	-44.6%	-33.7%	-41.9%

**Source:**

Wang, Michael, Q., model results of Beta Version of GREET 1.6, Argonne National Laboratory, Argonne, IL, August, 2001.

**Note:**

See page preceding Table 3.6 for acronym definitions.